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Use of Micrometeorological Parameters in the Establishment of a VOC (Volatile Organic Compounds) Monitoring Network

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This Report is part of the National Network for Environmental Management Studies Program conducted under the auspices of the Office of Cooperative Environmental Management — U. S. Environmental Protection Agency. As part of an ongoing volatile organic compounds (VOC) ambient air sampling network study using whole-air samplers, this report evaluates the uses of meteorological data in a VOC ambient air sampling activity. The report determines the minimum requirements for, type of, and usage procedures for meteorological instruments and the ways in which synoptic and on-site meteorological data can be integrated into an overall VOC sampling study. This report would be of interest to those persons interested in the procedures necessary to integrate meteorological data into a VOC ambient air emmission study.

Conclusions based on this study indicate that a detailed understanding of synoptic and on-site meteorology is a critical factor in selecting days for a successful VOC ambient air sampling test. Several minimum meteorological instrumentation requirements are needed, one of which is a tripod based, portable station with a self contained power source. Real-time viewing and electronic data logging of the wind speed and direction, as well as temperature and relative humidity, will allow the definition and verification of the sampling network centerline.

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THE USE OF MICROMETEOROLOGICAL PARAMETERS IN THE ESTABLISHMENT OF A VOC MONITORING NETWORK

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Disclaimer

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EXECUTIVE SUMMARY

As part of an ongoing University of Kansas and U.S. EPA, Region VII, volatile organic compounds (VOC) ambient air sampling network study using whole-air samplers, a NNEPS Fellowship sponsored project was conducted to evaluate the uses of meteorological data in a VOC ambient air sampling activity. The goals of the NNEPS study were to determine the minimum requirements for, type of, and usage procedures for meteorological instruments and the ways that synoptic and on-site meteorological data can be integrated into an overall VOC sampling study.

A synoptic scale meteorological forecast was used in selecting sampling days which had favorable meteorological conditions. Two portable meteorological stations were deployed at the sampling site with one station being near the emitting source and the other approximately one kilometer downwind of the source. Meteorological variables measured and logged included the wind speed and direction, temperature, and the relative humidity. The sampling network centerline was defined by using the mean wind direction from the downwind meteorological station. The logged data were processed and the results used to verify the sampling network centerline.

Conclusions based on this study indicate that a detailed understanding of the synoptic and on-site meteorology is a critical factor in selecting days for a successful VOC ambient air sampling test. Several minimum meteorological instrumentation requirements are needed and include a tripod based, portable station with a self contained power source. Real-time viewing and electronic data logging of the wind speed and direction, and temperature and relative humidity will allow the definition and verification of the sampling network centerline.

Introduction

During the time period from April, 1988 through March, 1989, the University of Kansas, in cooperation with the U.S. EPA, Region VII, is involved in a field study to evaluate the use of whole-air stainless steel samplers in determining whether specific volatile organic compounds (VOC) are being released from an isolated, rural source. In general, this study involves placing whole-air samplers in a predetermined sampling network downwind from an emitting source. The exact determination of the sampling network location relative to the emitting source is critical for providing meaningful results and is dependent on four principle factors:

* Topographic features which may restrict deployment of the whole-air samplers.
* Land use restrictions, such as private property that is not accessible to the sampling team.
* The type and geometry of the VOC source.
* The general synoptic meteorology and the micrometeorology of the specific ambient air sampling site.

In principle, the first three factors can be viewed as defined constraints and can be dealt with through proper planning. However the meteorological factor is very unpredictable and must be dealt with on a case-by-case sampling event basis. Because of this, a detailed synoptic meteorological investigation and an on-site micrometeorological investigation must be performed before the ambient air sampling network can be deployed at the VOC source. In addition, an understanding of the on-site meteorology during a sampling run aids in determining what physical processes may be acting on the plume as it passes over the network.

As a part of this larger study[1], a detailed analysis of the meteorological data requirements for a VOC study was done through the National Network for Environmental Policy Studies (NNEPS) fellowship program. This report summarizes the results of the work performed under the NNEPS program.

Several procedures were developed to integrate meteorological data into a VOC ambient air emission study. These findings are outlined in this report and include the following major components: the general requirements for meteorological instrumentation and data recording devices at a VOC sampling test; the use of synoptic data in selecting the time and day for a VOC sampling event; the effective use of synoptic scale meteorological parameters and on-site meteorological data during an actual VOC sampling run; the requirements for data processing needed to extract information from the raw meteorological data output; and, the integration of meteorological data with the VOC ambient air concentration data resulting from an actual sampling event.

Micrometeorological Requirements for a VOC Study

Variables measured

In performing a successful VOC ambient air emission study, a detailed understanding of the local real-time meteorology is needed for proper sampling network layout and analysis of the ambient air VOC concentration findings. This is best accomplished by using portable meteorological instruments. These instruments must measure specific variables: namely, the wind speed and direction, temperature, and the relative humidity.

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[1] The final technical report from this study, dealing with the use of Whole-air samplers in determining whether a specific VOC compound is being released from an isolated rural source, will be released in the Spring of 1989. The report will include all the results of the 1988-1989 sampling season including concentration data and integrated on-site meteorological data.

Wind Direction and Speed -- Measurement of the wind direction and speed allows the determination of the average wind direction ($\overline{dir}$) and wind velocity ($\bar{V}$) and associated deviations of wind direction (σ_{dir}) and wind velocity (σ_V). A clear understanding of the average wind direction is critical to ambient air sampling network deployment in relation to the emission source. Knowledge of the wind direction deviations and the wind velocity allows the determination of the stability regime present during the sampling period (1). Stability information is useful, since it indicates the degree of low-level ambient air mixing. The level of mixing directly effects the dispersion characteristics of the VOC plume. For example, an unstable condition results in low-level turbulent mixing. This causes the VOC plume to disperse rapidly making downwind ambient air concentration measurements difficult to obtain.

Temperature and Relative Humidity -- The measurement of the ambient temperature and relative humidity, although not as critical as the wind components, is useful in analyzing downwind concentration results. Generally, the temperature tends to effect mixing through surface heating (2) and controls the rate of VOC evaporation from the emitting source. For example, low ambient temperatures (10° C) will produce lower emission VOC evaporation rates and a slower VOC plume dispersion rate.

The effect of the relative humidity on a VOC plume is not fully understood. Possible interactions may include an effect on VOC evaporation due to vapor pressure and atmospheric density contributions of the water vapor. Temperature and humidity measurements are also needed in running various VOC dispersion models, such as DEGADIS and CHARM™.

Instrument needs and requirements

The meteorological instrumentation for a VOC ambient air emission study can

range from simple to complex devices. As previously indicated, the meteorological station must measure the wind components, temperature, and humidity. Independent of the complexity of the meteorological instruments selected, there are minimum requirements that must be met in the selection process. These minimum requirements are discussed in the following paragraphs.

Instruments

Wind -- The most common wind direction and wind speed measuring devices are a wind vane and anemometer, respectively. Other devices that provide the same parameters are also available and these include three-dimensional propeller systems and sonic anemometers. In a study of this type, a good wind vane and cup anemometer will produce satisfactory results. Such a unit should have an anemometer with a low threshold velocity (.34 m/s typical) and a wind vane having a small distance constant and damping ratio (4 meters and .6, respectively). In addition, the wind vane should have a 540° potentiometer to minimize cross-over problems on recording charts. This problem, common with 360° potentiometer units, can produce erratic wind traces when the wind direction corresponds to the sensor trip point. Both the wind vane and cup anemometers should be mounted two meters above the ground at the sampling site.

Temperature and Relative Humidity -- Measurements of the temperature and relative humidity can be done using several electronic methods. The most common temperature sensors include thermistors and platinum wire resistors, with the platinum wire sensor normally being the more stable (but more expensive). Humidity is usually measured with various lithium chloride and resistive sensors. The minimum accuracy needed for temperature and humidity measurements is 1.0° (C) and 3%, respectively. A response time of two minutes for both instruments is satisfactory. Independent of the sensors used, adequate shielding from solar and

reflected radiation must be provided. This is most easily accomplished by using a "bee hive" type radiation shield, several of which are available commercially. The radiation shield mounts over the top of the temperature and humidity probes.

Signal Conditioning and Logging Requirements

In addition to the basic meteorological instruments, some form of instrument signal conditioning and logging is normally required. Most sensors do not directly output scaled measurements, but generate voltage or current values. These indirect values must be signal conditioned into a readable format. In selecting such a device, the price and ease-of operation become very important factors. The ability to select different scales and degrees of conditioning through users' switches aids in proper data collection. In addition, self-contained battery operation is preferable. In many cases, the manufacturers of the sensors offer matching conditioning equipment. In some circumstances manufacturers of specialized sensors (such as radiometers) do not offer conditioning devices. In these cases other conditioners can be used. The key is to specify exactly the type of sensor and the type of conditioning needed to the alternate conditioner supplier, so that a compatible match can be made.

In addition to conditioning, some form of data logging must be included in the meteorological station package. In general, this can range from paper strip-chart recorders to computer-based storage devices. Such a device should provide a means to examine real-time data at the sampling site and should log average values every one minute. An electronic-based storage device (cassette tape or floppy disk) is preferable since such devices can be easily used with post-processing analysis. An ideal set-up includes a strip-chart display for real-time viewing and an electronic logger for data storage.

Station Configuration

The use of the above instruments in the field requires a tripod mounting system. A tripod offers flexibility, ease of assembly, and rugged construction at a moderate cost. Many tripod weather packages have special mounting brackets which allow instruments to be attached easily and precisely. The only strict requirement that the mounting system must meet is its ability to extend to a standard height of two meters without loss of system stability.

Meteorological Stations Selected for this Study

Two different portable meteorological stations that meet the above requirements were used in this study. These are a Climatronics Electronic Weather Station (EWS) and a custom station designed and assembled by the study team members. The EWS station consisted of a tripod-mounted instrument package (wind speed and direction, temperature, and relative humidity), signal conditioning and strip-chart recorder unit, and a separate electronic data logger. The individual sensor and equipment specifications are as follows:

Instruments

Variable	Sensor	Accuracy
Temperature	Thermistor	0.5° C
Relative Humidity	Strain gauge	5 %
Wind speed	Light chopper	.34 m/s*
Wind direction	Potentiometer	3°

* Threshold velocity

Conditioning -- Self contained, battery powered unit providing user selectable scaling switches. A built-in paper strip recorder and data output jack are standard features.

Data Logger -- Campbell Scientific 21X data logger. Features include battery operation, real-time viewing, and cassette tape storage.

The custom station was also tripod mounted. This station consisted of a three-dimensional propeller anemometer, combined temperature and humidity sensor

and an electronic net radiometer. The sensor and equipment specifications are as follows:

Variable	Sensor	Accuracy
Temperature	thermistor[1]	.2° C
Relative Humidity	resistance	5 %
Wind components	3 - D propellers[2]	.3 m/s*
Net radiation[2]	thermopile[3]	10.6 $Wm^{-2}mV^{-1}$

* Threshold velocity

1 Campbell Scientific model 207 temperature/rh probe
2 Gill model 8274 UVW propeller anemometer
3 Radiation Energy Balance Systems model Q*4 radiometer

Signal Conditioner and Logger -- Both signal conditioning and logging was done with a Campbell Scientific 21X logger (cassette tape storage capability included).

Both of these stations were easy to set up and use and produced excellent results.

Meteorological Usage In Planning and Directing a VOC Sampling Test

A synoptic and on-site meteorological investigation is an important component in choosing and directing a VOC ambient air sampling test. In general, this is accomplished by obtaining a good weather forecast for the sampling period and augmenting this with the deployment of an on-site meteorological station.

Synoptic Conditions Required for a Study

In planning a successful VOC study, certain synoptic meteorological conditions should be present. They include: consistent and moderate winds, low level atmospheric stability (stable to neutral range), and the absence of fog or precipitation. Favorable conditions for this type of study can often be found in a pre-cold front passage situation. Conditions which should be avoided during a sampling event include wandering and/or gusty winds, precipitation, and strong

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2 The net radiation was included in this station as an aid in determining the stability.

instability in the lower atmosphere. Such conditions are typical of frontal activity (wandering and/or gusty winds associated with high pressure settings).

For example, the synoptic setting for the August 31, 1988 sampling event (tests No. 1 and 2) represents favorable conditions (Fig 1). Moderate winds from the south prevailed at an average velocity of 5 m/s. Skies tended to be clear with neutral to slightly stable conditions in the lower atmosphere. As indicated on the surface map, the entire Midwest region showed an absence of precipitation.

The ability to select suitable sampling days is dependent on some form of weather forecast. During the ongoing 1988-89 sampling season, National Weather Service (NWS) surface and upper air forecast maps are being used as a guide in making decisions. This method has the advantage that wind patterns and frontal locations can be studied in some detail. It is understood that the availability of such maps may be restricted and that an alternate form of forecasting may be needed. If the NWS weather forecast information is not available, local airports may offer a forecast which is detailed enough for sampling event decisions and does give information pertaining to the low-level atmospheric winds and the conditions aloft. If such forecast are not available, a local news media forecast is usually sufficient to provide guidance in selecting sampling days by noting forecasted frontal system passages and predicted wind conditions. However, such forecasts do not provide any information describing low level atmospheric stabilities.

Planning a VOC sampling event based on the synoptic forecast does have limitations. Forecasts longer than 24 hours should be avoided due to the general uncertainty inherent in these long range forecasts. In addition, local conditions such as strong surface heating may result in low-level instabilities and rapid wind fluctuations. Such conditions tend to give poor sampling results.

WEDNESDAY, AUGUST (31) 1988

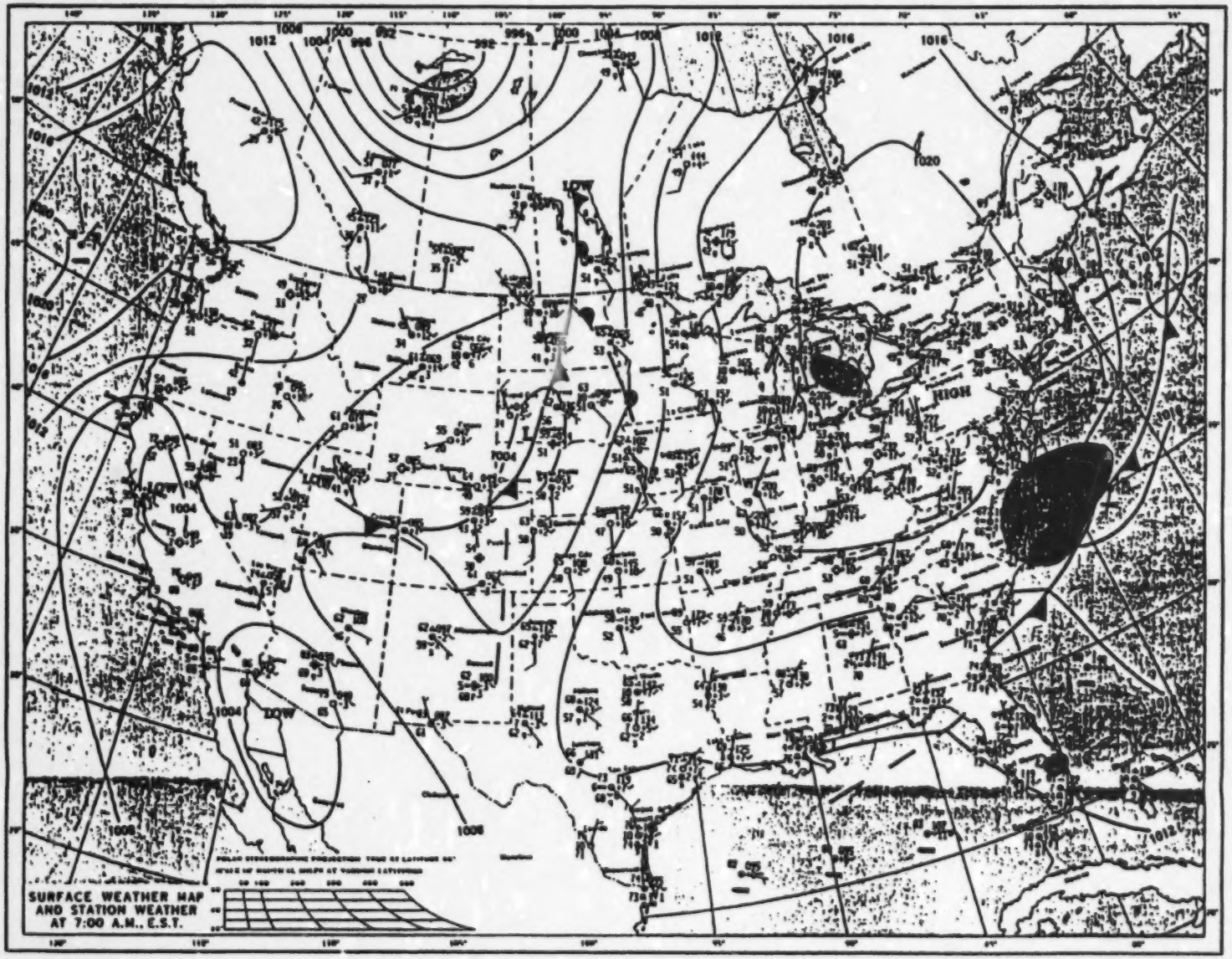

Fig 1 Surface Weather Map for Wednesday, August 31, 1988 (Test No. 1 and 2)

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For this reason, an initial on-site investigation must be performed prior to sampling.

On-Site Meteorological Investigation and Data Collection

As described previously, a clear understanding of the on-site meteorology is critical in performing a successful ambient air VOC sampling event. An on-site meteorological station allows the determination of three principal factors critical to the sampling run. These are the determination of the mean wind direction, the ability to respond to transition shifts in the wind direction, and an initial estimate of the low-level stability regime present in the atmosphere.

Arrival and Set-up at the Sampling Site

Once a synoptic investigation and forecast has indicated that conditions are favorable for sampling, the portable meteorological station must be set up, on-site, to monitor the prevailing meteorological conditions on the sampling day. A typical set-up includes a visual estimation of the predominant wind direction, followed by the deployment of a meteorological station near the emission source. In order to obtain the best possible data, the station should be leveled and the wind instruments aligned to true north with a reliable compass. The station should be located as close as possible to the source in order to fully represent the micrometeorological conditions initially affecting the plume. However, care should be taken such that large buildings and vegetation have a minimal effect on the operation of the meteorological station. Such structures can produce erratic turbulent wind conditions, giving rise to false results on critical wind data. The VOC source being characterized for ambient air concentration profiles in this study is a gasoline transfer station. This transfer station complex consists of several buildings and numerous large storage tanks (3 to 5 meters in height).

After careful review of the wind data from our initial sampling test, it was determined that these structures introduced turbulent eddies into some of the wind data. Since accurate knowledge of the wind direction and deviations is needed in the sampling network operation, a second weather station was set up 1 km down wind from the emission source meteorological station. This station is set up in an area containing no structures and is used to define the true ambient wind direction and speed. Once the station is in operation, a 15 to 25 minute examination of the data should be performed, taking note of the wind direction and the directional variations. This is best accomplished with a strip chart. This procedure will define the compass direction of the network centerline. In addition, an initial estimation of the low level stability can be obtained by noting the variations in the direction. Large swings in direction (>10°) tend to indicate unstable conditions, while small swings (<10°) represent the more favorable neutral to stable conditions. Since the success of the test involves sampling a plume passing over the ambient air sampling network, major changes in wind direction can void a test. Turning and/or backing winds are often noticed during the initial monitoring period. If such conditions are present, the test should be delayed until the winds become reasonably constant. These changing conditions are especially prevalent during early morning (8:00 AM) hours as daytime coupling of the lower and upper atmospheric surface layers take place.

Monitoring during the test

Continual monitoring of the wind direction and wind variations should continue even after the test is underway. This is particularly true if multiple sampling events are being run back to back. Often the wind direction will show a 10° to 15° shift due to surface heating and further upper and lower atmospheric coupling. Detailed knowledge of these shifts will allow adjustment of the

sampling network centerline, avoiding poor test results.

Examples of Initial Wind Monitoring

Figures 2 and 3 show the initial wind-monitoring strip charts for tests 7 and 13. These two tests illustrate the contrast between erratic and consistent wind conditions.

Test 7 is an example of highly variable and wandering winds. After setting up the meteorological stations, wind monitoring was initiated at 10:00 AM on 12 October, 1988. Initially, the winds showed a general bearing of about 165°. The direction then began to show backing to the east, and by 10:20, winds showed a 135° bearing. Because of this the test was postponed until 10:35, after which winds turned back to about 160°. At this point a decision was made to start the test with a sampling network centerline of 160°.

This day was not favorable for sampling for two principal reasons. First, the winds showed a wandering nature which made the task of defining the sampling network centerline difficult. The second reason concerned the directional deviations, with extreme fluctuations ($\sigma_{dir} >> 10°$) clearly indicating that an unstable stability regime was present in the lower atmosphere. Even though conditions were not favorable, the test was conducted and produced VOC ambient air concentration results showing a skewness from the original sampling network centerline toward the east.

Test 13 is an example of a sampling event conducted under consistent wind flow conditions. In this test, the initial atmospheric monitoring showed a steady mean wind direction of about 200°. Directional variation was small ($\sigma_{dir} < 10°$) suggesting neutral to stable conditions. At 10:14 A.M. (CDT) on 13 December, 1988, the test was initiated with a sampling network centerline bearing of 200°. The wind data remained consistent throughout the sampling event, and

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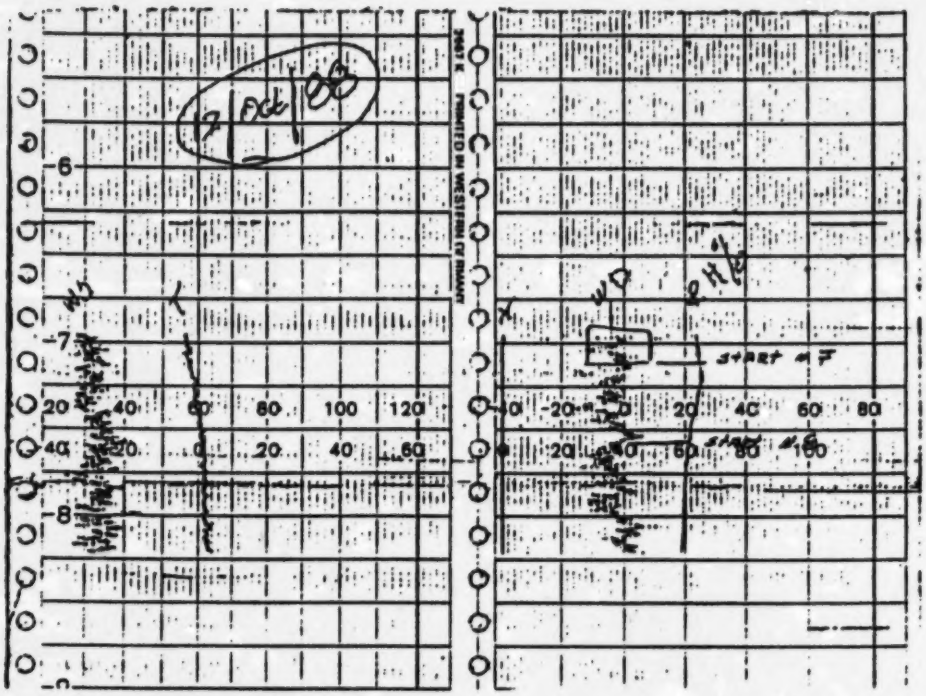

Fig 2 Wind-monitoring Strip Chart for Test No. 7

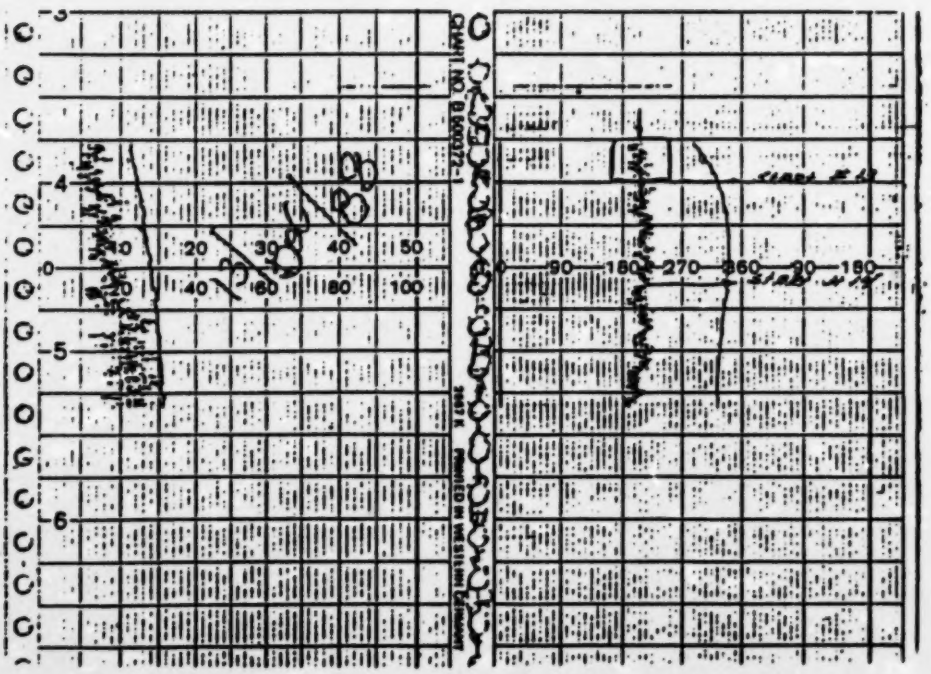

Fig 3 Wind-monitoring Strip Chart for Test No. 13

the final result was a successful test.

Post-Field Data Conversion and Processing

Post-field processing of the collected meteorological data involves three phases and includes the following: data format conversion, calculation of sampling averages and standard deviations, and the determination of stability conditions present during each test.

Format conversion.

As indicated in the instrumentation requirements, some form of data logging is needed to store data for analysis. Depending on the storage media and device, some type of data conversion may be needed. The data logger used on this project consisted of a cassette-based storage device. Information written to cassette is stored in a binary format specific to the data logger. Because of this, a computer-based translation card is used to convert this data into an ASCII format. This converter was supplied by Campbell Scientific and includes a PC 201 converter designed to operate in an IBM PC type computer. After conversion, the resulting data is in a comma-delineated ASCII format (Fig 4). A second converter (a CSI PC 205 card) is used to split this data into a column-delineated format (Fig 5). This data format is readily usable in most commercially available spread sheet programs and computer languages (BASIC, FORTRAN, etc.). As a quality control measure, the converted data is plotted, using a spread sheet, and examined for possible cassette recording errors.

Calculation of Sample Period Averages and Standard Deviations.

Basic statistical calculations are important in the verification of a

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201,327,1030,4.101,4.101,189.3,0,.187,304.7,8.87,49.72
201,327,1031,4.704,4.704,215.4,0,-.012,305.4,8.74,49.19
201,327,1032,4.948,4.948,197.7,0,.325,306.8,8.93,49.62
201,327,1033,4.057,4.057,200.3,0,.128,309.1,8.99,49.59
201,327,1034,3.922,3.922,198.8,0,.418,310.5,9.07,49.58
201,327,1035,3.2,3.2,185.5,0,.476,311.2,9.24,49.46
201,327,1036,4.861,4.861,192.5,0,.581,311.9,9.11,49.23
201,327,1037,5.29,5.29,184.1,0,-.023,313.4,9.15,49.09
201,327,1038,5.219,5.219,183.9,0,.198,314.8,9.15,49.14
201,327,1039,5.43,5.43,189.4,0,-.058,315.6,9.15,49.13
201,327,1040,3.906,3.906,181.3,0,-.058,317.7,9.25,49.28
201,327,1041,4.919,4.919,184.4,0,-.081,317.7,9.34,49.13
201,327,1042,5.085,5.085,187.1,0,.314,319.1,9.22,48.96
201,327,1043,5.306,5.306,184.7,0,.349,320.6,9.23,48.96
201,327,1044,6.478,6.478,193.3,0,.267,321.4,9.18,48.8
201,327,1045,8.03,8.03,191.3,0,-.035,322.1,9.11,48.74
201,327,1046,7.35,7.35,197.9,0,-.012,323.5,9.15,48.85
201,327,1047,3.99,3.99,213.8,0,.43,324.3,9.16,48.95
201,327,1048,3.16,3.16,220.3,0,.244,326.4,9.15,49.02
201,327,1049,5.569,5.569,198,0,.023,326.4,9.28,49.16
201,327,1050,3.366,3.366,217.7,0,.43,327.9,9.37,48.94
```

Fig 4 Weather Data in converted Comma Delineated ASCII Format

TIME	VELOCITY	DIRECTION	RADIATION	TEMPERATURE	HUMIDITY
10.5	4.101	189.3	304.7	8.87	49.72
10.51667	4.704	215.4	305.4	8.74	49.19
10.53333	4.948	197.7	306.8	8.93	49.62
10.55	4.057	200.3	309.1	8.99	49.59
10.56667	3.922	198.8	310.5	9.07	49.58
10.58333	3.2	185.5	311.2	9.24	49.46
10.6	4.861	192.5	311.9	9.109999	49.23
10.61667	5.29	184.1	313.4	9.149999	49.09
10.63333	5.219	183.9	314.8	9.149999	49.14
10.65	5.43	189.4	315.6	9.149999	49.13
10.66667	3.906	181.3	317.7	9.25	49.28
10.68333	4.919	184.4	317.7	9.34	49.13
10.7	5.085	187.1	319.1	9.22	48.96
10.71667	5.306	184.7	320.6	9.229999	48.96
10.73333	6.478	193.3	321.4	9.18	48.8
10.75	8.03	191.3	322.1	9.109999	48.74
10.76667	7.35	197.9	323.5	9.149999	48.85
10.78333	3.99	213.8	324.3	9.16	48.95
10.8	3.16	220.3	326.4	9.149999	49.02
10.81667	5.569	198	326.4	9.28	49.16

Fig 5 Weather Data in Column-Delineated Format

correct sampling network deployment and for calculating the stability regime present during a sample run. For these reasons, simple averages and standard deviations are calculated for the wind direction and wind speed. Simple averages are also calculated for the temperature and relative humidity. Because wind components are important in the determination of a successful monitoring effort, large standard deviations (>10° and >3 m/s, respectively) for these two variables indicate less than ideal sampling conditions.

Determination of the Stability Regime during a Test.

The determination of the stability regime present during a sampling run is a principal factor in describing what type of low-level atmospheric mixing is affecting the plume. Stability can be determined in two ways. The first approach uses the Pasquill method that relies on a combination of the wind speed and the daytime, incoming radiation (insolation)(Table 1).

Simple Pasquill Classification

Surface wind speed m/sec	Daytime insolation		
	Strong	Moderate	Slight
< 2	Unstable	Unstable	Unstable
2 - 4	Unstable	Unstable	Unstable
4 - 6	Unstable	Neutral	Neutral
> 6	Neutral	Neutral	Neutral

This method is simple to use but is not very accurate, since insolation must be estimated. An alternate method uses the Gilford classification, which relies on the standard deviation of the wind direction as the indicator of stability class (Table 2). This method has the advantage of needing only one meteorological variable to define the stability regime.

Table 2

Gilford Classification

Stability Class	Directional Deviation
Very Unstable	>25
Moderately Unstable	20
Slightly Unstable	15
Neutral	10
Slightly stable	5
Moderately stable	2.5

The stability classification method used in this study consisted of a combination of the Gilford and Pasquill methods. In theory, both classifications should give the same stability condition, although some discrepancies will normally result due to the different indicator variables used. Because of this, the Pasquill method was used to define the basic generic stability (neutral or unstable). This was followed up with the Gilford method to further divide the stability classification into smaller increments (table 2).

An example of this procedure follows for test 8 ran on 12, October, 1988. This day was characterized by clear skies, an average wind speed of 2.1 m/s, and a wind direction standard deviation of 30°. Using the time of year and the cloud cover, the incoming insolation was determined to be moderate (table 3)

Table 3

Insolation Estimation

Time of Year	Cloud Cover
Nov 4 - Feb 4 = slight	Clear skies = no change
Feb 5 - April 16 = moderate	70 % middle clouds = lower one insolation category
April 17 - Aug 28 = Strong	70% low clouds = lower up to two insolation categories
Aug 28 - Nov 4 = moderate	Overcast = same as low clouds

The basic stability was next determined using the Pasquill classification (table

1). Using this method a generic stability of unstable is obtained.

A refinement of this stability was next preformed using the Gilford classification (Table 2). Due to the large wind direction deviation (30°), the Gilford method indicates that a very unstable stability class existed for the sampling run.

In general, this combined method will give satisfactory estimations of the stability. Currently, an approach is being developed which will use the net radiation, wind speed, and directional deviation to automatically determine the stability class. This proposed method will remove the uncertainty associated with estimating the insolation.

Integration of Meteorological Data with VOC Data

The integration of the collected meteorological data with the VOC data principally involves verification of the sampling network centerline with the observed wind direction. Presently, work is also being conducted that will lead to the use of meteorological data in describing plume transport and dispersion.

Verification

Verification of the sampling network centerline is one of the most important uses of the recorded meteorological data. The VOC sampling network used by the team is a modified version of the network used on earlier test (3). In general, this network consist of three downwind radials separated by 45° and centered on the emitting source (Fig 6). Two rows of samplers are positioned outward from the source, one at the property line and the other out to one kilometer from the VOC source. Along the centerline radial, samplers are co-located at both the property line and the outer location in addition to a single upwind sampler. Since the initial wind direction is used in defining the sampling network

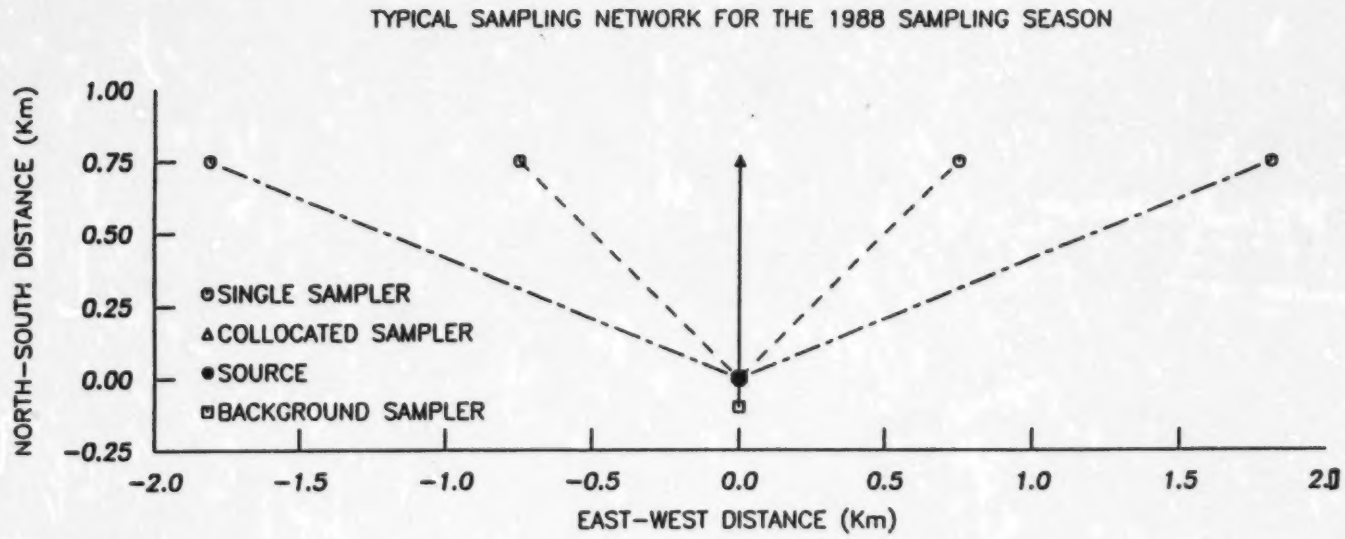

Fig 6 VOC Sampling Network

centerline, this compass bearing must be verified with wind data taken during the actual VOC sampling test. Performing this verification aids in explaining why maximum ambient air VOC concentration results may show skewing away from the original sampling network centerline.

This verification is simple to perform and involves comparing the average wind direction recorded during the test with the original sampling network centerline. A rule of thumb developed over many test implies that a network centerline and average wind direction (flow vector) comparison of less than 10° indicates a proper centerline definition. Larger deviations (> 10°) suggest a wind shift during the test and may result in maximum VOC concentration values being skewed to one side or the other of the centerline.

Example of Verification

An example of this verification is given for test 3 performed on the 14 September, 1988. The initial sampling network set-up defined the centerline as 270° from compass true north. The test ran with this bearing and the resulting average wind direction (Fig 7) was determined to be from 92° (272° flow vector). A comparison of the network centerline and the wind direction gives a 2° difference. From this result, it is expected that the maximum VOC ambient air concentrations should be found in the samplers deployed along the network centerline. A review of the concentration data for this run agrees with the expected result (Table 4).

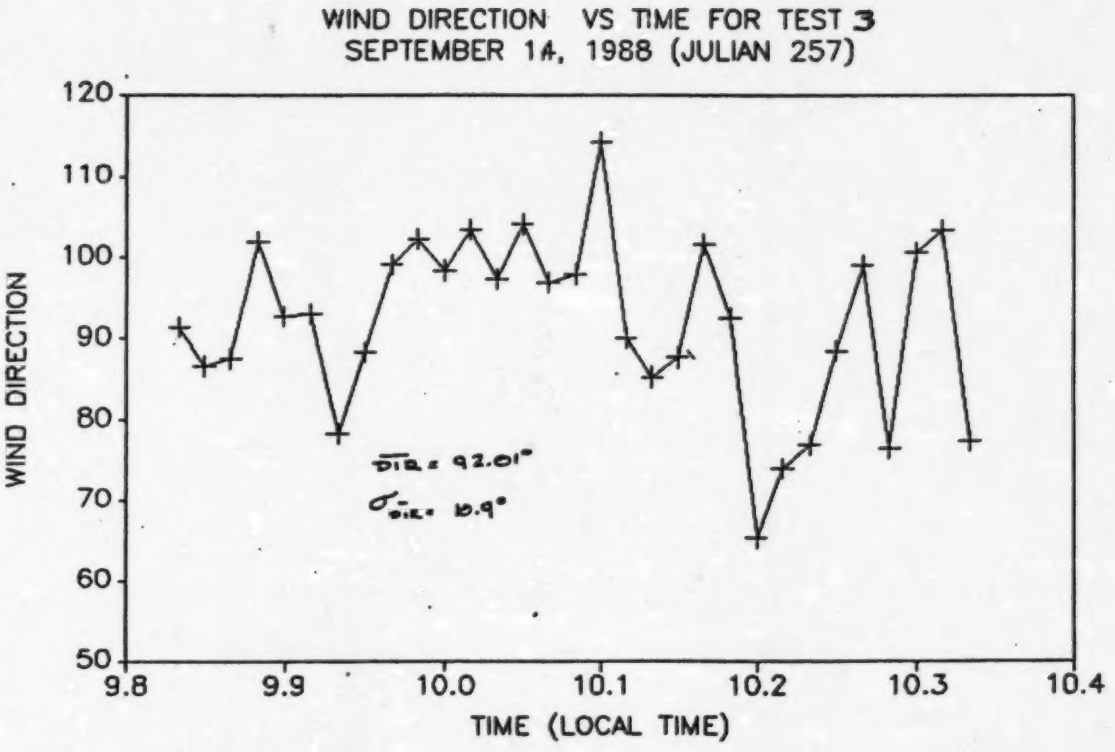

Fig 7 Average Wind Direction for Test No. 3

Table 4

Concentration Results for Test 3

Isopentane (ppb)

	45° Left	Centerline	45° Right
Inner Arc	212.3	19591.4	1845.4
Outer Arc	4.20	1824.8	15.0

The data tend to show that the maximum plume-derived ambient air concentration passed over the centerline samplers with very little skewing occurring on the 45° offset samplers.

Future Work

Currently two spin-off areas of research are being considered. These are trajectory wind analysis and VOC plume dispersion dynamics. Trajectory analysis is a powerful tool in describing air movement over a surface. In trajectory analysis, the path or trajectory of an individual air parcel is mapped as it moves over the sampling network. This procedure involves using an upwind and downwind measurement of wind direction and speed. Since tests 7 through 14 have had such measurements, trajectory analysis may provide a means to explain why certain downwind concentration data resulted (such as skewing).

In addition to the trajectory analysis, the dispersion characteristics of a VOC plume in relation to specific meteorological variables is being studied. These variables include the net radiation, relative humidity, stability regime, and the temperature. The effects of these variables have not been fully quantified. Examples may include how the dispersion of a plume is affected by low-level mixing (stability and net radiation) and the transition phases of the VOC compounds in the plume such as evaporation and expansion due to temperature and humidity. At present, neither of these areas has been fully explored. The

hope is that further development of these areas will help to refine the understanding of how a VOC plume affects the environment.

Conclusions

Meteorological data is a critical factor in performing a successful VOC sampling test. In this paper, several requirements and procedures have been outlined for the use of meteorological instruments and data in a VOC ambient air sampling project.

In selecting meteorological instruments, several minimum requirements are needed. These include a tripod based, portable meteorological station with a self-contained power source. Variables that must be measured by the meteorological station are the wind speed and direction, temperature, and relative humidity. For efficient operation, some form of real-time viewing (such as a strip chart) and electronic data logging should be a capability of the meteorological station.

A successful VOC sampling test is highly dependent on the synoptic meteorology and the on-site micrometeorology. In planning a test, a good synoptic forecast is useful in making a decision as to whether favorable meteorological conditions (consistent winds and lack of precipitation) will be present on the day of the VOC sampling test. An on-site micrometeorological investigation determines whether favorable conditions exist (constant wind direction and neutral to stable stability conditions) for initiation of a VOC ambient air sampling event; this investigation also defines the VOC sampling network centerline.

The collection (logging) of the four meteorological variables at the time of the test allows this data to be integrated into the overall VOC ambient air

concentration sampling results. This includes the verification of the sampling network centerline, as well as possible explanations for maximum VOC ambient air concentration skewing and VOC plume dynamics.

Bibliography

1 Hanna, S. R., et al. Handbook on Atmospheric Diffusion. Technical Information Center, U.S. Department of Energy, 1982.

2 Rosenberg, N.J., et al. Microclimate: The Biological Environment. A Wiley-Interscience Publication, New York, 1983.

3 Marotz, G. A., Lane, D. D., and Carter, R. E., Jr.,"Refinement of a Detection and Analysis Approach to Volatile Organic Compound Release Characterization Using a Whole-Air Technique," Technical Report to the U.S. EPA Environmental Protection Agency, 1987.